

PAPERS

Towards optimal trauma care

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'For the want of timely care millions have died of medicable wounds' (The Act of Preserving Health by John Armstrong [1709–1779])

SUMMARY

This paper examines some problems related to trauma care, and, at the same time, discusses some solutions, particularly stressing the need for a trauma system in Great Britain.

INTRODUCTION

Ironically, there have already been attempts to introduce a trauma system, yet none have come to fruition. The first attempt was by Sir Robert Jones during the building of the Manchester ship canal. He designed a very good system for care of the injured worker but, unfortunately, it did not sustain itself. The next effort was made by William Gissane at the Birmingham Accident Hospital with significant contributions by Roscoe Clark and Peter London. Unfortunately, both hospital and concept have not been successful and will soon be moved. It may have been doomed to failure since it was 'free-standing' and not affiliated with a university. More recently, the Platt report was brought forth, but, again, nothing has come of it.

It is hoped that this paper can build a case for a trauma system using statistics gathered from the United States. It does not seem that Great Britain is very different, and comparisons will be made where possible. It is hoped that this paper can convincingly show that trauma is the most significant health and social problem facing industrial countries today.

Table 1 Comparison of trauma between Great Britain and the U.S.A.: prevention

	<i>Great Britain</i>	<i>U.S.A.</i>
Mandatory seat belts	80%	5% (Few States)
Airbag	0	0
Drunk driver	Yes	Yes
Motorcycle helmets	Yes	No
Handguns	Minor	Major
Drugs	Problem	Major problem
Burns	—	Fire safe cigarette

Magnitude of the problem

Trauma is the leading cause of death and disability among Americans between the ages of 1 and 38. In 1982 there were approximately 165 000 deaths from accidents and violence in the United States. For each death there are at least two to three permanent disabilities. Statistics compiled by the Department of Health and Human Services indicate that for Americans between the ages of 15 and 24, the combined death rate from motor vehicle accidents, homicides and suicides has risen by 50% since 1976, and now account for 80% of all deaths in this age group. Urban violence is a particular problem, with the number of murders increasing from 8464 in 1960 to a projected 27 000 in 1983.

Trauma primarily affects young, productive citizens, and the estimated cost for death, disability and loss of productivity exceeds \$240 million a day. The total annual cost is a staggering \$87.4 billion in wages losses, medical expenses, insurance administration, fire loss, motor vehicle property damage and indirect work lost. Trauma patients consume 19 million hospital days annually, more than all heart patients, and four times those needed by cancer patients. In the past decade death rates for heart disease and stroke have fallen by 22% and 32% respectively. The overall mortality rate for cancer has increased by 6% from 1950 through 1977, but mortality from stomach, rectal, cervical and uterine cancer has decreased. Since 1977, the death rate for accidents has risen by approximately 1% per year.

If the trauma problem is to be addressed in a rational way there must be an understanding of the pathophysiology and epidemiology, similar to any other approach to treatment of a disease process. Data from our institution (Baker *et al.*, 1980b) and others (Lowe *et al.*, 1985) have shown that death from trauma has a trimodal distribution. These deaths can be further characterized as immediate, early and late. The pathophysiology is different for each peak. It also should be remembered that for each death there is an associated permanent or partial disability which constitutes 350 000 patients and 9 million patients, respectively, on an annual basis.

Immediate deaths. The first peak is death within seconds or minutes of injury. Invariably, these deaths are due to lacerations of the brain, brain stem, upper spinal cord, heart, aorta or other large vessels. Although few of these patients can be saved, some deaths have been avoided in large urban areas with rapid transport (Baker *et al.*, 1980b; Harnar *et al.*, 1981).

Early deaths. The second death peak occurs within the first two to three hours after

injury. These deaths are usually due to subdural and epidural haematomas, haemopneumothorax, ruptured spleen, lacerations of the liver, fractured femur or multiple injuries associated with significant blood loss. Almost all of these injuries are treatable with available methods. However, the interval of time between injury and definitive treatment is critical.

Late deaths. The third death peak occurs days or weeks after the injury, and in nearly 80% of these cases the cause of death is sepsis, infection and multiple organ failure.

The paper examines each of these peaks in more detail and, in particular, the solutions that could lead to a reduction in mortality and disability.

IMMEDIATE DEATHS

Over 50% of all trauma deaths fall into the immediate category. With the exception of a few urban centres, surgical care has little to offer these patients. Furthermore, there is essentially no hope that improved care or biological research can reduce the tragic numbers in this immediate category. The only possible way of addressing this category of trauma deaths is through prevention. However, it seems unlikely that an effective prevention campaign can be mounted since very complex social problems such as the following are at issue.

Automobile accident deaths

In 1981 there were 50 800 deaths caused by motor vehicle crashes. An estimated 55% involved drivers who were legally drunk. Social efforts to control drunk driving have recently met with modest success due to groups such as MADD (Mothers Against Drunk Drivers) and RID (Remove Intoxicated Drivers). However, although there is, initially, a decrease in crashes, deaths and injuries when stricter drunk driving laws are passed, there has invariably been relaxation, and reduced enforcement of laws, leading to an increase in death and injury rates near to those prior to the stricter laws.

The most promising interventions to reduce deaths and injuries involving drunk drivers are listed below.

Improved crash worthiness of motor vehicles. The state of the art is the Research Safety Vehicle (RSV) developed and built by firms including Chrysler and Volkswagen under contract with the Department of Transportation. The RSV was designed so that occupants could walk away from a 50 m.p.h. head-on crash. No new technology was needed; the RSV was designed to include, among other things, airbags, fuel cells (as used in racing cars), anti-skid brakes, roll bars, Securiflex windshield (which greatly reduce facial injuries), brake lights installed at the rear window level and 'soft' front ends. According to the National Highway Traffic Administration, all the safety features added only \$1200 to the price of a \$6000 car.

Administrative revocation of driver's licenses. A driver's licence could be immediately revoked by an arresting officer if the driver's blood alcohol level was 0.10 (100 mg%) or greater. This inflicts a swift punishment that is then followed by a court trial. The

penalty for driving without a licence must be increased to deter those who have had their licences revoked from driving. The 1982 experience in the State of Iowa with administrative revocation shows a significant reduction in deaths and injuries involving drunk drivers. Some estimates claim a reduction of nearly 50%.

Devices in vehicles that limit drunk drivers. Although still prototypes, devices have been developed that may, at a later date, prove useful in preventing alcohol- or drug-impaired persons from driving a motor vehicle. Examples of this approach are: (1) a breathalyser connected to the ignition system, such that the vehicle will not start if a high alcohol content is registered; (2) a small microprocessor that requires a code or psychomotor skills to start the vehicle; and (3) a device that registers faulty and erratic driving behaviour by sounding the horn and blinking the headlights. So far, field testing has been limited and results variable.

Increased excise tax on alcohol. It has been demonstrated in various countries that with an increase in the price of alcohol, there is a corresponding decrease in cirrhosis rates and drunk-driving crashes. This tax could have a double benefit if it were used to pay for increases in trauma care costs, particularly in rural areas where government subsidy is probable.

Random breathalyser tests. Australia has recently enacted random roadside breathalyser tests. If the driver is found to have an alcohol level of 0.05 (50 mg%) he is fined \$300. If the breathalyser alcohol level is 0.08, (80 mg%) the driver is fined \$1000, with immediate revocation of his licence. Although this programme has only been in effect for 5 months, the immediate impact has been a very dramatic reduction in alcohol-related motor accident deaths and disabilities.

This is only a partial list of strategies to prevent drinking-driving crashes. It is noteworthy that by improving the crash worthiness of motor vehicles (installation of airbags, etc.) that all occupants are protected in crashes whether alcohol is involved or not.

There is yet another effective way to reduce motor vehicle accident deaths: the use of seat belts or passive restraints. Statistics from America are fairly dismal, since only 11% of motor vehicle occupants wear a seat belt if they drive a large car, and only 14% if they drive a small car. The Road Safety Committee of the Australasian College of Surgeons recognized that the wearing of seat belts could effectively reduce motor vehicle deaths and disabilities. By instituting a public campaign, legislation was introduced requiring mandatory use of seat belts in Australia in 1970. By 1977, there had been a 27% reduction in motor vehicle fatalities. Similar results could be achieved or bettered by the use of such passive restraints as the airbag.

Homicides

Of the 26 000 murders in 1982, approximately 11 000 were committed with a handgun. In our experience at San Francisco General Hospital, one in every six attempts at homicide with a gun is successful, but only one in every sixteen attempts with a knife. There are 60 million handguns in the United States, and it seems impossible to do away with them. A more realistic approach to handgun control is to enforce mandatory registration. This would allow responsible citizens to own a handgun, and make it easier for police to identify 'outlaws' who have an unregistered handgun in their possession.

Such an approach has been tried in Michigan and Massachusetts, with a significant reduction in homicides committed with a handgun. A state-by-state enactment of such handgun control does not seem realistic and should be addressed by a federal law. Great Britain does not share this problem.

Deaths due to fire

There are approximately 6000 burn deaths annually and 75 000 admissions to hospitals with over a half of these patients left with permanent disabilities or cosmetic deformities. Tragically, more than one-third of these deaths, and approximately 10% of the disabilities, can be attributed to careless cigarette-smoking. The average American cigarette has additives, both to the paper and to the tobacco, that cause the cigarette to burn for an average of 28 minutes. If these additives were removed, the average cigarette would burn out in 3 or 4 minutes. Coincidentally, most American upholstered furniture and mattresses require over 4 minutes of exposure to a cigarette before it ignites. The problem and the solution are obvious. Removal of the additives, would not change the taste of the cigarette, but would make the cigarette relatively more fire-safe, and would reduce unnecessary fires, deaths, disability and property loss. Unfortunately, the tobacco manufacturers will not remove these chemicals voluntarily, and this will undoubtedly require federal legislation. Just as in the case of motor vehicle accidents and the drunk driver, the person who smokes the cigarette also causes the death and disability of innocent victims sharing the same apartment building or hotel who are caught in the fire. Other examples of burn prevention are equally compelling. They include the wearing of flame resistant bed clothing; the use of smoke alarms to detect fires earlier; shorter cords on appliances to prevent fires, and reduction in water heater temperatures to prevent scalds in small children.

Motorcycle accident deaths

Another controversial prevention issue is the mandatory use of motorcycle helmets. From 1967 to 1976, a federal highway safety standard required that all states enact and enforce motorcycle helmet laws. During this period, fatalities were reduced by 50%. In 1976, Congress revoked the federal sanctions against states not complying with the helmet standard. As a consequence, at least 35 states have repealed or weakened the helmet laws in the past few years. This has resulted in a 40% increase in fatalities. A study from the University of California concluded that the 'use of a safety helmet is the single critical factor in the prevention or reduction of head injuries'. It is also interesting that two other studies (Insurance Institute of Highway Safety, 1980; 1981) document the social burden of unhelmeted motorcyclists. Of 71 motorcyclists hospitalized at Denver General Hospital, only 38% were covered by commercial insurance or workman's compensation. Thus, 59% of the bills were paid by taxpayers. In a similar study from the Maryland Institute for Emergency Medical Services, 40% of 65 patients had no medical insurance coverage.

Drug-related deaths

Equally controversial is the issue of drug legalization. It is doubtful that the legalization

of drugs would solve the drug problem: it would simply decriminalize it. During the past 15 years at San Francisco General Hospital the number of innocent victims injured by penetrating trauma has increased to approximately 40%. Almost all these incidents are the result of drug trafficking, and the need of addicts to pay for their habit. Most drug addicts must pay for their habit by illegal methods; 'pimping, prostituting, pushing or pilfering'. At the very least, one or two states should establish pilot programmes to evaluate our current drug laws and the decriminalization of drug use.

It is likely that drug use is not significantly related to the legality of the drugs. Experience in the United States suggests that alcohol use was not decreased by prohibition and may even have been increased because of the aura or mystique of being prohibited. Drug use is probably similar, and there is no reason to think usage would be affected by decriminalization. All the negative effects that accompany it, however, would be reduced.

Although this is not a complete catalogue of prevention issues, it represents some of the problems we face. Clearly, these issues are complex and inextricably woven into our mores. It is unfortunate that prevention, which is difficult to achieve, is seemingly the only way to reduce immediate trauma deaths. It is also ironic that although prevention is not only the best way to save lives, it is the cheapest—crisis intervention is always expensive. Ultimately, prevention would also affect the other two death peaks.

EARLY DEATHS

Approximately 30% of all trauma deaths fall into the early category. Most of these deaths can be further subdivided into two more categories: brain injuries and haemorrhage. In order to reduce death and disability from these two categories, some fundamental principles must be followed. Both injury categories require definitive surgical care within the shortest period of time in order to achieve acceptable results. The concept of reducing the time lag from injury to definitive surgical care involves at least two parts of any trauma system; prehospital and hospital. Both of these components will be examined in detail.

Prehospital trauma care

Three types of injury account for virtually all prehospital deaths: direct cerebral and high spinal cord injury cause approximately 50–55% of deaths; exsanguination due to thoracic, abdominal and major vascular injuries, or severe pelvic or long bone fractures accounts for 30–40%; airway obstruction, open or tension pneumothorax and hypoxia from other causes accounts for 10–15% of the total.

In patients who die with potentially salvageable head injury, the usual cause of death is airway obstruction or aspiration causing acute hypoxia. Patients with massive head injuries which result in apnoea or brain stem herniation early are not salvageable. Those who are salvageable usually do not develop extreme elevation of intracranial pressure

for at least 30–60 minutes. Preventable death in the field is, therefore, usually due to the airway problems which occur with unconsciousness, not to the head injury directly. If this is understood it becomes clear that the essential skill the paramedic can provide is endotracheal intubation, which at one provides ventilation and airway protection. A secondary benefit is reduction in cerebral oedema by hyperventilation. The neurological lesion itself cannot be treated in the field and is best handled by rapid transport to prompt, definitive neurosurgical care (Seelig *et al.*, 1981). Spinal protection in appropriate cases, particularly of the cervical spine, is also an essential manoeuvre which can be quickly accomplished. Since oedema does not usually develop for 30–60 minutes, mannitol in the field is quite unlikely to be of benefit, and might aggravate coexisting hypovolaemia.

The second most common cause of death is exsanguination. What can the paramedic offer? For isolated sources of external bleeding, direct pressure to control it is the obvious answer. The majority of patients who exsanguinate, however, do so from internal bleeding which is not controllable without surgical intervention. The only treatments which are potentially beneficial are the establishment of an intravenous (IV) line with rapid fluid administration, and the use of the pneumatic anti-shock garment. Both of these interventions are controversial and their use must be considered in a risk-benefit analysis. It is impossible to stabilize the critically injured. After extrication and establishment of an airway nothing should delay transport to definitive surgical care. Application of the pneumatic anti-shock garment, splints and insertion of an IV is optimally done *en route*. The only other therapeutic intervention necessary at the scene is protection of the spine.

Finally, what of the acute airway problems that are lethal? The great majority of these are effectively treated by endotracheal intubation, as it protects from aspiration and provides a closed pneumatic system for ventilation. It has been thought, up to the present time, that the oesophageal obturator airway (EOA) was an effective alternative to endotracheal intubation that did not require a high level of training for usage, but it has now been shown in two different systems (Sacramento and San Francisco) that the EOA does not function as well as previously thought, and the incidence of inadequate ventilation with it is unacceptably high (Smith *et al.*, 1982). As a result, it appears that endotracheal intubation, though more demanding in training time and skill required, is sufficiently superior to justify this investment. When the benefits in comatose patients are also considered, the benefits seem overriding.

It is clear from the above discussion that the principal reduction in mortality for prehospital traumatic injury will come from endotracheal intubation and rapid transport. Trauma patients are fundamentally different from cardiac arrest patients who are customarily resuscitated and stabilized before transport. Yet, both share the same EMS system and ultimately both benefit from rapid transport. It does not make sense to plan separate cardiac and trauma prehospital rescue and delivery. Yet, some detractors of trauma systems argue that trauma care will increase prehospital time. Nothing could be further from the truth. Many communities have successfully planned and implemented prehospital rescue and treatment which does not involve lengthening the time of the prehospital transport nor does it lead to unnecessary loss of life. Table 2 shows a comparison of prehospital problems.

Table 2 Comparison of trauma between Great Britain and the U.S.A.: prehospital

	Great Britain	U.S.A.
Paramedics	Few	Too many*
Policy	Nearest hospital	Some designation of trauma centres
Care	'Immediate'	Not applicable

*Except in rural areas.

Hospital trauma care

The case for prompt definitive surgical care for trauma patients, once they arrive at a hospital, is even more compelling than the prehospital care. This hospital care must involve a team of surgeons, anaesthesiologists and nurses, either in-house or 'promptly' available to treat trauma patients as soon as possible after their arrival. This concept has recently been dramatically demonstrated in the care of patients with neural trauma. Seelig *et al.* (1981) have shown a dramatic change in outcome when the neurosurgical procedure was done within 4 hours of injury. The same data suggest that results are even more favourable when definitive surgery is provided within 2 hours of injury.

Is there any evidence that this prompt surgical care is being provided under our current standard of practice? The evidence is overwhelmingly to the contrary. Table 3 lists some of the studies that have been done in the United States to document hospital

Table 3

Author	Year	Type of study	Comments	Preventable deaths or inappropriate care
Van Wagoner	1960	Service records autopsy	Males age 18–55 Retrospective study	200/606 (33%)
Frey <i>et al.</i>	1969	Autopsy	25% hospital deaths Preventable retrospective	28/150 (18%)
Gertner <i>et al.</i>	1972	Autopsy	Abdominal trauma only Retrospective	17/32 (53%)
Trunkey & Lim	1974	Autopsy	Comparison trauma centre/ non-trauma centres Retrospective	11/15 (73%)
Detmer <i>et al.</i>	1977	Statewide survey	Retrospective	167/565 (30%)
Foley <i>et al.</i>	1977	Autopsy	Retrospective	11/43 (25%)
Houtchens	1977	Hospital records	Retrospective	53/108 (49%)
West <i>et al.</i>	1979	Autopsy	Comparison of two regions	11/33 (33%)
Dove <i>et al.</i>	1980	Hospital records	Retrospective	59/108 (55%)
Trunkey	1982	Autopsy	Retrospective	129/308 (42%)
Lowe <i>et al.</i>	1982	Hospital records	Prospective—mortality difference between small and large hospitals	34/135 (25%)
Stennes	1983	Hospital records	Prospective—3 month only	13/88 (13.6%)

trauma care. In general, these studies clearly show that one third of all hospital trauma deaths could be prevented. The data further suggest that this is primarily a problem with people and not with a facility, equipment or resources. For example, Lowe *et al.* (1983) showed that the average surgical consultant response time was 1.26 hours. It is impossible to provide prompt, definitive surgical care under these conditions.

For more than 40 years the American college of Surgeons Committee on Trauma has been an advocate of improved trauma care. Since 1976 the Committee on Trauma has formalized its recommendations in the form of guidelines for optimal care of the trauma patient (Hospital Resources for Optimal Care of the Trauma Patient, 1979). There are those who are sceptical of this approach, and one of the reasons given has been that there is no evidence that regionalized trauma care makes a difference, but there are at least three examples that now exist proving the efficacy of regionalized trauma care: the United States Military experience, West Germany and Orange County, California.

Historical perspective

The care of the injured patient can be traced back into antiquity. According to Majno (1975) the Greeks had a crude but effective system of care for their injured soldiers. In the *Iliad* there are recorded 147 wounds of which 31 involved the head (100% mortality) and the rest were extremity and torso wounds with approximately 70% mortality. The wounded were taken from the battlefield and transported to nearby ships or barracks (*klisiai*) where they received their surgical care. This care was often rudimentary, and apparently the Greeks could not amputate since there are no recorded cases. Torso wounds were not universally fatal and there are recorded instances of survival after pneumothorax and evisceration.

Oriental medicine, in general, lagged behind, particularly in China. Surgeons there were treated as third-rate graduates, in contrast to India. In the *Artashastra* it is recorded that the Army did indeed have an ambulance service with surgeons (Majno, 1975). Surgical instrumentation was fairly advanced, and there were many methods of removing arrows and spears.

Early Roman military surgery was both expedient and political. The wounded soldiers were assigned to the homes of patricians where they received nourishment and care. As the Roman Empire expanded it was necessary to build special quarters for the sick and wounded, the *valetudinaria*. The archaeological remains of at least 25 of these structures have been found spread out along the boundaries of the Roman Empire. They were very sophisticated in design and concept, allowing the Roman surgeons to

Table 4 Comparison of trauma between Great Britain and the U.S.A.: hospital

	<i>Great Britain</i>	<i>U.S.A.</i>
Trauma system	None	Beginning
Attendings	Not registrars	Residents
Training	Minimal?	Documented minimal
Response time	Prolonged	Moderate

care for up to 10% of the Roman soldiers. It is interesting to note that Great Britain had more trauma centres during Roman times than they do now. Another group subject to traumatic wounds were the gladiators. Galen spent three years as a surgeon to the gladiators and left us a fairly vivid account of wound care. Unfortunately, many of Galen's observations and treatments were inaccurate and they persisted into the Middle Ages.

Wound care during the Middle Ages was generally abysmal. With the exception of a few surgeons, there was no organized attempt to care for the wounds of soldiers or peasants. The most notable effort was the remarkable work of Ambrose Pare. Pare introduced new concepts on the care of the wound and ligation of vessels, but did little to provide a stable, organized approach to battlefield wounds. Lack of money, resources and the unstable political environment of the Reformation undoubtedly contributed to this.

A systematic approach to care of the wounded did not evolve until the early 1800s when Baron Larrey introduced the *ambulance volante* (flying ambulance) and the concept of operating on patients as close to the battlefield as possible. He was also a master at developing support elements to provide care for the wounded during major campaigns, often travelling distances of over 3000 miles. Unfortunately, he was thwarted at almost every attempt by the army quartermaster and after he retired from military service most of the concepts that he had developed were soon forgotten. With the American Civil War it soon became obvious that in order to maintain morale and to rapidly return soldiers to duty, it was necessary to provide expert surgical care as quickly as possible. Other valuable lessons have been learned in our more recent conflicts. Reduction in mortality and morbidity has been achieved by shortening the time lag between injury and definitive surgical care. Echelons of care have been developed with rapid evacuation as soon as the patient has had life-saving surgery in order to expedite rehabilitation and return to duty or discharge. Unfortunately, these lessons have had to be relearned with almost every conflict and only recently have been applied to civilian injuries.

Examples of trauma systems

During World War I, the time lag from injury to surgery was 12–18 hours with an overall mortality of 8.5%. This was reduced during World War II to 6–12 hours, and a mortality rate of 5.8%. One of the most dramatic reductions in the time lag from injury to definitive care occurred during the Korean Conflict. The United States Army Medical Corps decided to bypass the battalion aid station and take the injured soldier directly from the field to the Mobile Army Surgical Hospital (MASH). This is analogous to bypassing emergency rooms where prompt definitive surgical care is not available, and going to the regionalized trauma centre. The average time lag from injury to definitive care during the Korean Conflict was 2–4 hours and overall mortality was 2.4%.

This tactic was improved upon in the Vietnam Conflict when casualties were taken directly from the battlefield to the Corps Surgical Hospital. One study showed that the average time lag from injury to emergency care was 65 minutes and another study found the time lag from injury to definitive surgical care was 81 minutes. Mortality was

reduced to 1.7%. This military experience should have been an incentive and a model for improvement in civilian trauma care. Unfortunately, this has not been the case except in a few isolated instances.

The second example that trauma care systems can improve trauma care comes from West Germany. During the late 1960s West Germany studied U.S. methods and techniques of providing battlefield care in Vietnam. In 1970 they applied these methods virtually throughout the country and established trauma centres along the major autobahns. Integral to their trauma centre concept is rapid prehospital transport which primarily involves the use of helicopters, but also includes ground transport. Ninety per cent of all the citizens of Germany are no more than 15 minutes from a designated trauma centre.

As a consequence of this regionalized system, the mortality rate from motor vehicle accidents, since 1970, has dropped from 16 000 per year to 12 000 per year, a reduction of 25%. It is probably no coincidence that this reduction coincides remarkably closely to the preventable death data shown in most American studies (33%). The German system is not only strong in prehospital and hospital care, but also involves an excellent rehabilitation programme. Most survivors return to productive lives.

Other countries including Switzerland, Austria and Israel also have excellent trauma systems. The United States has islands of excellence where trauma systems have been developed such as in Maryland, Houston, Dallas, Louisville, Seattle and Detroit.

One of the best examples of the value of a trauma centre, or system, can be found in Orange County, California. Table 3 refers to the original Orange County Studies. As a consequence of the second Orange County Study five trauma centres were designated in June of 1980. A recent study (West *et al.*, 1983) has examined the results and impact of these designated trauma centres. To my knowledge, this is the first time that data are available to compare trauma care before and after the establishment of trauma centres.

These data have shown that preventable deaths were reduced from 73% to 9% when the patients were treated in any one of the five designated trauma centres. If the patient was inappropriately triaged to a hospital that was not a trauma centre the preventable mortality remained at 67%. The study further documents that all appropriate surgery was performed in the trauma centre. In addition, patients did not die because other hospitals were passed by *en route* to the trauma centre. This finding is consistent with that from Vietnam where battalion aid stations were bypassed.

The evidence seems to overwhelmingly show that regionalized trauma systems improve the immediate outcome in life-threatening injuries and disability. They also have other very important functions including: the training of surgeons, other specialists, and nurses in the care of the injured patient. They should also be integral to regional disaster plans, education of the public, and serve as a focus for research. It is this latter function, that leads us into our third death peak.

LATE DEATHS

The final category, late deaths, accounts for approximately 20% of all trauma deaths. Eighty per cent of these are due to sepsis and multiple organ failure which seem to be

causally related. Risk factors that have been identified include shock, head injury, peritoneal contamination and malnutrition, which leads to infections and sepsis late in the course of the patient's injury. This may, in turn, be related to the failure of the patient's host defence and immune system. The exact causes have not been elucidated. Once sepsis is obvious the patient develops progressive organ failure including heart, kidneys, liver, lung, brain and haemopoietic system. The mortality is high and is directly related to the number of organ systems involved.

The answer to why the trauma patient is at risk from sepsis and multiple organ failure lies in research and an increase in knowledge. This need for basic trauma research and improved education has led the American College of Surgeons Committee on Trauma to the conclusion that more Level I trauma centres are needed to provide these resources. This need for improved research is not without its problems. The National Institute of Health spends very little of its research dollars on trauma research. National priorities are clearly directed towards cancer and heart disease, yet trauma accounts for more years of lost life than cancer and heart disease combined. One solution would be to have a National Institute of Trauma similar to the National Institute of Cancer and the National Institute of Heart and Lung Disease. Such an institute would serve multiple purposes. The institute could focus on trauma as a health and social issue. The institute could place equal emphasis on research and prevention, health care delivery and the solution of this third category of trauma deaths. Funding of such an institute is problematic in a time of restricted resources.

Rehabilitation

One of the most significant deficiencies in trauma care in the United States is the lack of an integrated rehabilitation system. Most disabling injuries are due to neurological and orthopaedic injuries. With the exception of some very excellent spinal cord rehabilitation centres not enough emphasis has been placed on returning the injured patient to work. This, obviously, would involve not only physical rehabilitation but it might also require job retraining and treatment for the emotional trauma that accompanies physical trauma. The spinal cord rehabilitation system is a model example of how regionalized rehabilitation centres can make a difference in increased longevity and productivity. This approach should be applied to trauma in general.

OTHER PROBLEMS

In addition to prehospital, hospital and rehabilitation problems, there are others such as trauma training (Report to the American Association, 1981), surgical availability (Rhodes *et al.*, 1982) and post-operative care (Strauch & Bligh, 1983). These additional problems only serve to contribute to inconsistent, disorganized and fragmented trauma care. In a recent unpublished study carried out by the Committee on Trauma of the American College of Surgeons, a questionnaire was sent to all chairmen of state and provincial (Canada) committees on trauma (Table 5). These individuals represent a

Table 5 ACS-COT study: summary

94% felt care of the injured was a 'problem'
40% could not identify surgeons in their state or province committed to trauma care
79.2% found that trauma care in the emergency room was by a non-surgeon
74.5% felt that surgeons recently appointed to medical staffs were marginally trained in trauma

cross-section of community hospitals and university practice. One hundred per cent compliance in return of the questionnaire was achieved. The majority of the state chairmen thought that trauma care in their region was suboptimal, and 94% felt that care of the injured was a major problem in American surgery. Forty per cent of the state and provincial chairmen felt that they would not be able, or could only with difficulty identify the surgeons in their state or province who were committed to excellence in trauma care. The overwhelming majority of state and provincial chairmen felt trauma care was not optimally or well organized in their regions. Significantly, the state and provincial chairmen felt that the responsible individual in charge of managing seriously injured persons in the emergency department was a qualified surgeon for only 20.8% of the time. In 15% of instances, a surgical resident was in charge, and, in the majority of cases, an emergency room physician, nurse or physician's assistant was the responsible individual.

The state and provincial chairmen also had some interesting perceptions on the training and commitment of surgeons in their regions. In 52.8% of the responses, the chairmen felt that there was some question as to the commitment of surgeons caring for injured victims. Significantly, 74.5% of the respondents felt that surgeons recently appointed to medical staffs were marginally trained in the care of trauma patients; this is borne out by other studies mentioned later.

There are other problems as well. Recently, questionnaires were sent to all medical school deans, and all programme directors of general surgery programmes (Trunkey, 1982). The questionnaire to the deans documented some major problems. Not surprisingly, trauma is not a major part of a medical school curriculum. During the preclinical years, trauma prevention was offered in only one-half of the medical schools polled. In 17 medical schools, hypovolaemic shock is taught by the Department of Medicine and not by the Department of Surgery. Other problem areas included a decreased emphasis on trauma in the curriculum as compared to cancer and heart disease, and a paucity of trauma research. The questionnaire sent to the programme directors was equally indicting. For example, 46% felt that their residents were gaining more than 10% of their total operative experience on trauma patients. Yet, when this was checked against the applications to the American Board of Surgery for 1980, 95% of the 933 applicants were gaining less than 5% of their total operative experience on trauma patients. Possibly more significant is the fact that 18% of all surgery residents applying to the Board in 1980 did less than 10 trauma cases, and 47% of the residents did less than 20 trauma cases during their entire residency. Other problems identified by the programme directors related to research, research funding and specialist training of residents in a 'core curriculum' as it relates to trauma.

SOLUTIONS

Prehospital care of the trauma patient involves ambulances and personnel that provide care for all emergencies. Recently, emergency physicians have taken an active role in providing leadership for this component of emergency care. Although this approach is valid, surgeons must provide input into prehospital care as it relates to trauma. In most communities surgeons are conspicuous by their absence in such involvement.

Optimal care of the trauma patient in the hospital can only be provided when surgeons and anaesthesiologists are present to care for the critically injured on arrival. This implies that the hospital has been predesignated to care for accident victims, and public safety and ambulance personnel know of this capability. It further implies that the medical and administrative staff are committed to provide this service on a 24-hour basis and have the back-up system to handle many multiply injured patients. Not only will this lead to improved care and outcome, but it will also result in reduced costs. In most regions, this will simply mean designating a few hospitals to provide such care. Although this sounds simple, it has only been achieved in a few communities.

Rehabilitation is a particularly vexing issue. I believe that surgeons will have to provide a leadership role in developing regional rehabilitation systems modelled after the spinal cord injury centres. Many European countries are leaders in rehabilitative care, and the seriously injured accident victim returns to work in a relatively brief period of time when compared to the USA.

Finally, it is imperative that physicians become involved in trauma prevention. The Australasian College of Surgeons' Road Safety Committee has been a leader in prevention programmes, including the establishment of mandatory seat belt legislation, and other innovative programmes to remove the drunk driver from the road. Every community in the United States and Great Britain is in need of a physician who will provide leadership in trauma prevention. Ironically, it is prevention that is the least costly and yet could have the most dramatic impact on reducing death and disability.

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